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MOUNTED WHEELS *and* POINTS

Safe and Efficient Operation

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Critical Speeds

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Grinding Wheel Manufacturers Association

MOUNTED WHEELS *and* POINTS

Principles of
Safe and Efficient Operation
with Tables
of Critical Speeds

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1943

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FOREWORD

During recent years, a number of small high speed grinding machines have been introduced for use with mounted wheels and points. These run at various speeds, some of them being rated as high as 100,000 r.p.m. This makes it possible to operate even the smallest points at really efficient surface speeds. These more efficient speeds increased the potential utility of mounted points, which as a result quickly found a new place of importance in industry.

Relatively few difficulties in the field resulted from the use of the higher speeds, but in a few cases spindle failures did occur. In some cases spindles broke off, but more frequently they merely bent over at right angles. Also, excessive vibration at certain speeds seemed to persist under certain conditions.

As no satisfactory explanation of this behavior was offered, the Grinding Wheel Manufacturers Association assigned the problem to its Safety Committee and authorized that a comprehensive technical study be conducted. This study, which required more than a year's work, included observations of the effect of different speeds on wheels and spindles of various sizes, operating under closely controlled conditions. A non-technical summary of the results, including recommendations and operating rules is presented herewith.

The Grinding Wheel Manufacturers Association hopes that this presentation will result in a better appreciation of the several factors which have until now been difficult to understand. The Grinding Wheel Manufacturers Association believes that observance of the rules and recommendations herein outlined will result in not only safer but also more efficient operation of this very popular type of abrasive tool.

GRINDING WHEEL MANUFACTURERS ASSOCIATION
SAFETY COMMITTEE

MOUNTED WHEELS AND POINTS

Critical Speed of Spindles

Proper recognition of the "critical speed" is the most important factor in the safe operation of mounted points and mounted wheels. Operation at the critical speed is very apt to result in failure of the spindle, either through severe bending or fracture. A general understanding of what is meant by "critical speed" is therefore important.

Every spindle with a wheel or point mounted on it has a certain critical speed at which vibration due to deflection or whip tends to become excessive. This critical speed varies with the following conditions:

1. Dimensions of wheel—
2. Diameter of spindle—
3. Distance from support to base of wheel—

1. Increasing the size of the wheel (either diameter or thickness) will lower the critical speed.

   Reducing the size of the wheel (either diameter or thickness) will raise critical speed.

2. Increasing the diameter of the spindle will raise the critical speed, and reducing the spindle diameter will lower the critical speed.

3. Increasing the overhang (distance from end of support to base of wheel) will lower the critical speed. Reducing the overhang (pushing the spindle back into the chuck) will raise the critical speed.

The kind of steel of which the spindle is made has very little influence on the critical speed and this factor may therefore be ignored.

The critical speed is not measurably affected by the short taper and reduced diameter at the end of the spindle to which wheels of very small size are attached. For all practical purposes the critical speed for this type of spindle can be considered the same as though the spindle were of uniform diameter throughout its length.

It has also been established that the critical speed of the spindle is usually not influenced by the type or style of machine used. However, the condition of the machine spindle and bearings may to some extent modify the critical speed. Also, greater run-out and out-of-balance of the wheel as mounted, will decrease the critical speed.

Operating Recommendations

Tables I to VI indicate the critical speeds for various standard mounted wheels and points in combination with several standard spindle sizes and various overhangs. These are for smooth unthreaded spindles. For many common combinations the critical speeds can be read directly from the tables. For intermediate wheel and spindle sizes and overhangs not shown, the critical speed can be estimated accurately enough by interpolation.

Operation at or near the critical speed must be avoided. It is recommended that the wheels be operated at a speed not higher than 75% of the critical speed. (NOTE: This recommendation of 75% is arbitrarily established to insure a good factor of safety. Under certain conditions it may be permissible to operate up to 85% of the critical speed.) If it is found that the desired combination of conditions would result in operation at or too near the critical speed, a slight change in any one of the individual conditions may be all that is necessary to eliminate the danger of operating at the critical speed.

For instance, it is desired to operate a $\frac{3}{8}$ x $\frac{3}{8}$" wheel mounted on a $\frac{1}{8}$" spindle at 30,000 r.p.m. with the wheel projected about $1\frac{1}{2}$" beyond the end of the chuck. Reference to Table I will show that the critical speed of the spindle is 32,200 r.p.m. Hence it would be unsafe to operate under these conditions. Assuming that the speed of the machine cannot be reduced, obviously some other change must be made if operation at the critical speed is to be avoided. The following possibilities are suggested:

1. Reduce length of projection to 1" which raises critical speed to about 44,000 r.p.m.
2. Reduce diameter of wheel to $\frac{1}{4}$" which raises critical speed to 38,500 r.p.m.
3. Increase diameter of spindle to $\frac{3}{16}$" which raises critical speed to 49,000 r.p.m.

It will be noted that any one of these changes should make it safe to operate at 30,000 r.p.m., although the margin of safety by method 2 may not be as wide as desirable. Where possible, a wider margin of safety should be provided.

Threaded Spindles

The critical speed of mounted wheels and points with threaded spindles is lower than for similar wheels with smooth unthreaded spindles. Since the tables show the critical speeds for smooth spindles, the safe operating speeds for threaded spindles are considerably lower. For $\frac{1}{8}$" threaded spindles the operating speed should not exceed 50% of the speed shown in the tables and for $\frac{1}{4}$" threaded spindles it should not exceed 60%.

(NOTE: These recommended percentages are also arbitrarily established and under certain conditions it may be permissible to operate up to 55% and 65% respectively of the critical speed shown in the tables.)

Actual Speed of Machine

With most high speed machines and where overhang exceeds ½", it is usually not possible to increase the speed beyond the critical speed of the wheel spindle regardless of the rated speed of the machine. When the critical speed is reached vibration due to deflection or whip puts such a load on the machine that it cannot reach its rated speed when the rated speed is higher than the critical. This tends to hasten failure of the spindle and should be stopped as soon as noticed, and the conditions altered as required. Occasionally it is possible to increase the speed through and beyond the critical speed of the spindle, and it is then found that the mounted wheel or point operates smoothly at a speed considerably higher than the critical. This condition is seldom achieved, and cannot be predicted. Therefore, it is recommended that the operating speed be maintained at some point lower than the critical. However, under certain ideal conditions of trueness and balance it may be permissible, where necessary, to operate at a speed higher than the critical provided the speed shown in Table A is not exceeded.

Strength of Wheels

Mounted wheels and points are seldom made coarser than 60 grit and soft grades are seldom required. Hence the wheels and points themselves are usually strong enough to operate safely at a speed high enough to be highly efficient. However, under certain conditions, particularly where wheel is mounted with little or no overhang and where the larger wheel diameters are involved, it is possible to attain a speed considerably under the critical that might be high enough to be unsafe.

Table A shows the maximum speed that should be used for various sizes of wheels even though this be lower than the critical. This is based on the strength of average wheels commonly used. If for some special reason it is necessary to use wheels coarser than 60 grit or of unusually soft grades, the speeds shown in the table may be too high, and the maximum recommended by the wheel manufacturer should not be exceeded.

Chucks and Mounting

Worn chucks and lack of care in mounting sometimes result in considerable initial run-out. This may result in spindle failure or in wheel breakage when the wheel is brought into contact with the work.

Work Pressure

Work pressure, if excessive, can be the cause of trouble and a source of danger, through bending or fracture of the spindle even at speeds below the critical. Since it would be very difficult to measure the work pressure, it is not practical to set up any definite limitations. Ordinarily the work pressure will not be excessive unless an attempt is made to force the wheel beyond its cutting capacity. An experienced operator can tell whether or not a wheel or point is cutting free. If the wheel causes burning of the work, it is quite likely that excessive pressure is being used, especially if the spindle is of very small diameter. A softer grade of wheel may permit the desired rate of stock removal without using excessive pressure. If trouble is still encountered it may be necessary to reduce the rate of feed.

If the machine speed is safely below the critical speed as determined by Rule No. 2, and if the wheel runs smoothly when free, but not so smoothly when under load, it is quite likely that excessive pressure is being used, and this should be reduced as soon as the condition is noted.

CONDENSED OPERATING RULES FOR MOUNTED WHEELS AND POINTS

Rule No. 1. Maximum Safe Operating Speed

To determine the maximum safe operating speed for mounted wheels and points, two factors shall be considered (1) critical speed, and (2) limit of wheel strength.

1. Establish safe percentage of critical speed according to Rule No. 2.
2. Establish maximum speed according to Rule No. 3.

Whichever of these is the lower shall be considered the maximum safe operating speed.

Rule No. 2. Critical Speeds

(See page 3 for a detailed discussion of critical speed and the relationship of critical speed to safety.)

Tables I to VI indicate the critical speeds for various standard mounted wheels and points in combination with standard spindle sizes and various overhangs. These are for smooth unthreaded spindles.

(a) Mounted wheels and points with smooth unthreaded spindles shall be operated at a speed not more than 85% and preferably not more than 75% of the critical speed indicated in the tables.

(b) Mounted wheels and points with ⅛″ threaded spindles shall be

operated at a speed not more than 55% and preferably not more than 50% of the critical speed indicated in the tables.

(c) Mounted wheels and points with ¼" threaded spindles shall be operated at a speed not more than 65% and preferably not more than 60% of the speed indicated in the tables.

Exception: Under certain ideal conditions of trueness and balance it may be permissible, where necessary, to operate at a speed higher than the indicated critical speed, provided the speed shown in Table A is not exceeded.

Rule No. 3. Maximum Speed

(See page 5 for discussion of maximum speed based on the strength of the wheels.)

Table A shows the maximum operating speed for various diameters of mounted points and wheels. This speed shall not be exceeded even though it be lower than the safe percentage of the critical speed, as defined in Rule No. 2.

TABLE A

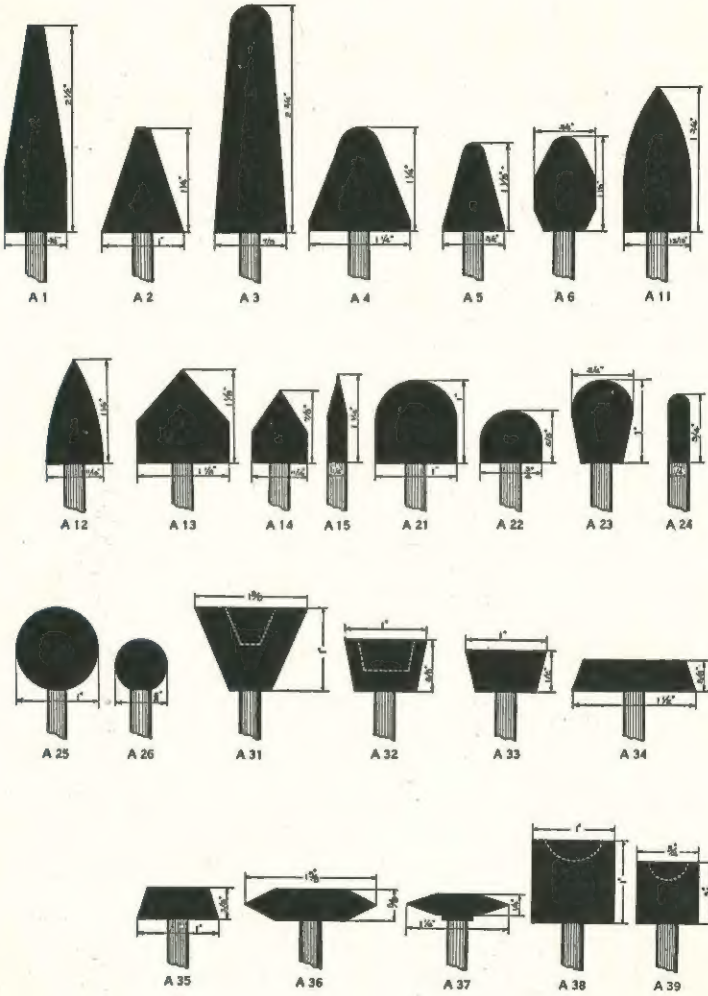
Outside Diameter of Wheel	Maximum Speed (R.P.M.)
¼	152,700
5/16	122,200
⅜	101,856
½	76,392
⅝	61,120
¾	50,928
⅞	43,648
1	38,196
1¼	30,560
1½	25,464
1¾	21,824
2	19,098

These speeds are based on the strength of vitrified mounted wheels and points of average grade. If for any special reason it is necessary to use wheels coarser than 60 grit or of unusually soft grade, the maximum speed recommended by the wheel manufacturer shall not be exceeded.

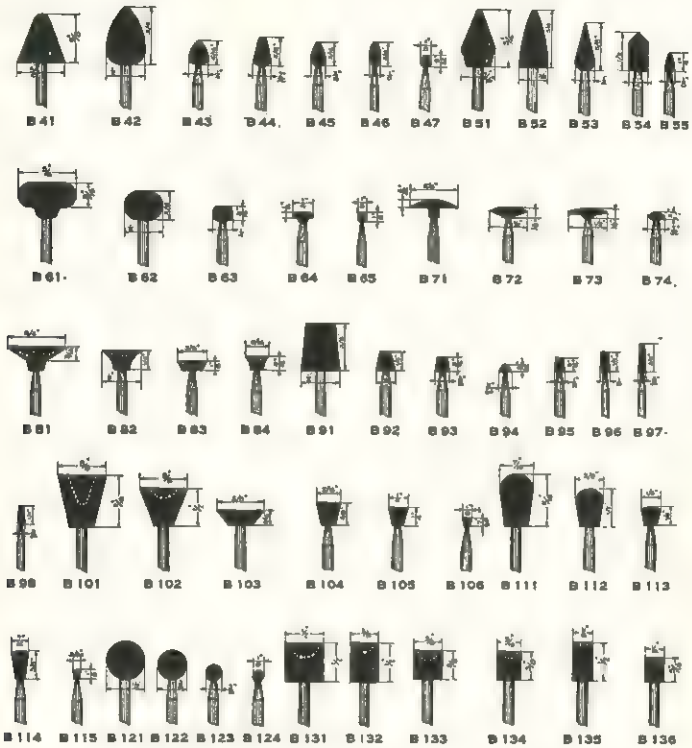
Rule No. 4. Work Pressure

Pressure between wheel and work shall at no time be so heavy that any considerable springing of the spindle will result. It is particularly important to observe this rule in connection with small wheels and points where the end of the mandrel that enters the wheel is of reduced diameter.

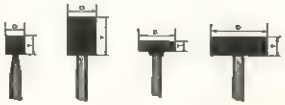
GROUP "A"—STANDARD SHAPES



GROUP "B"—STANDARD SHAPES



GROUP "W"—PLAIN SHAPES



MOUNTED WHEELS AND MOUNTED POINTS

GROUP A—(STANDARD SHAPES)

Shape No.	Size		Shape No.	Size	
	Diam.	Thickness		Diam.	Thickness
A 1	3/4	2 1/2	A 23	3/4	1
A 2	1	1 1/4	A 24	1/4	3/4
A 3	7/8	2 3/4	A 25	1	1
A 4	1 1/4	1 1/4	A 26	5/8	5/8
A 5	3/4	1 1/8			
A 6	3/4	1 1/8	A 31	1 3/8	1
			A 32	1	5/8
A 11	13/16	1 3/4	A 33	1	1/2
A 12	11/16	1 1/4	A 34	1 1/2	3/8
A 13	1 1/8	1 1/8	A 35	1	3/8
A 14	11/16	7/8	A 36	1 5/8	3/8
A 15	1/4	1 1/16	A 37	1 1/4	1/4
			A 38	1	1
A 21	1	1	A 39	3/4	3/4
A 22	3/4	5/8			

GROUP B—(STANDARD SHAPES)

Shape No.	Size		Shape No.	Size	
	Diam.	Thickness		Diam.	Thickness
B 41	5/8	5/8	B 71	5/8	3/32
B 42	1/2	3/4	B 72	1/2	3/32
B 43	1/4	5/16	B 73	1/2	3/32
B 44	7/32	3/8	B 74	7/32	3/32
B 45	3/16	5/16			
B 46	1/8	5/16	B 81	3/4	3/16
B 47	1/8	5/32	B 82	1/2	1/4
			B 83	3/8	1/8
B 51	7/16	3/4	B 84	5/16	3/16
B 52	3/8	3/4			
B 53	1/4	5/8			
B 54	1/4	1/2	B 91	1/2	5/8
B 55	1/8	1/4	B 92	1/4	1/4
			B 93	3/16	3/16
B 61	3/4	5/16	B 94	11/64	3/32
B 62	1/2	3/8	B 95	1/8	3/16
B 63	1/4	3/16	B 96	1/8	1/4
B 64	1/4	1/16	B 97	3/32	3/8
B 65	1/8	1/8	B 98	3/32	1/4

GROUP B—(STANDARD SHAPES)—(Continued)

Shape No.	Size		Shape No.	Size	
	Diam.	Thickness		Diam.	Thickness
B 101	5/8	11/16	B 121	1/2	1/2
B 102	5/8	1/2	B 122	3/8	3/8
B 103	5/8	3/16	B 123	3/16	3/16
B 104	5/16	3/8	B 124	1/8	1/8
B 105	1/4	1/4			
B 106	1/8	1/64	B 131	1/2	1/2
			B 132	3/8	1/2
B 111	7/16	11/16	B 133	3/8	3/8
B 112	3/8	1/2	B 134	5/16	3/8
B 113	1/4	1/4	B 135	1/4	1/2
B 114	7/32	3/8	B 136	1/4	5/16
B 115	3/32	1/8			

MOUNTED WHEELS AND MOUNTED POINTS

GROUP W—(PLAIN SHAPES)

Shape No.	Size		Shape No.	Size	
	Diam.	Thickness		Diam.	Thickness
W 141	3/32	5/32	W 156	1/4	1/32
W 142	3/32	1/4*	W 157	1/4	1/16*
			W 158	1/4	1/8*
W 143	1/8	1/8*	W 159	1/4	3/16*
W 144	1/8	1/4*	W 160	1/4	1/4*
W 145	1/8	3/8*	W 161	1/4	5/16*
W 146	1/8	1/2*	W 162	1/4	3/8*
			W 163	1/4	1/2*
W 147	5/32	1/32	W 164	1/4	3/4*
W 148	5/32	1/16			
W 149	5/32	1/4*	W 165	5/16	1/16
			W 166	5/16	1/8
W 150	3/16	1/16	W 167	5/16	1/4*
W 151	3/16	1/8*	W 168	5/16	...
W 152	3/16	1/4*	W 169	5/16	...
W 153	3/16	3/8*	W 170	5/16	1/2*
W 154	3/16	1/2*	W 171	5/16	3/4
W 155	13/64	1/4			

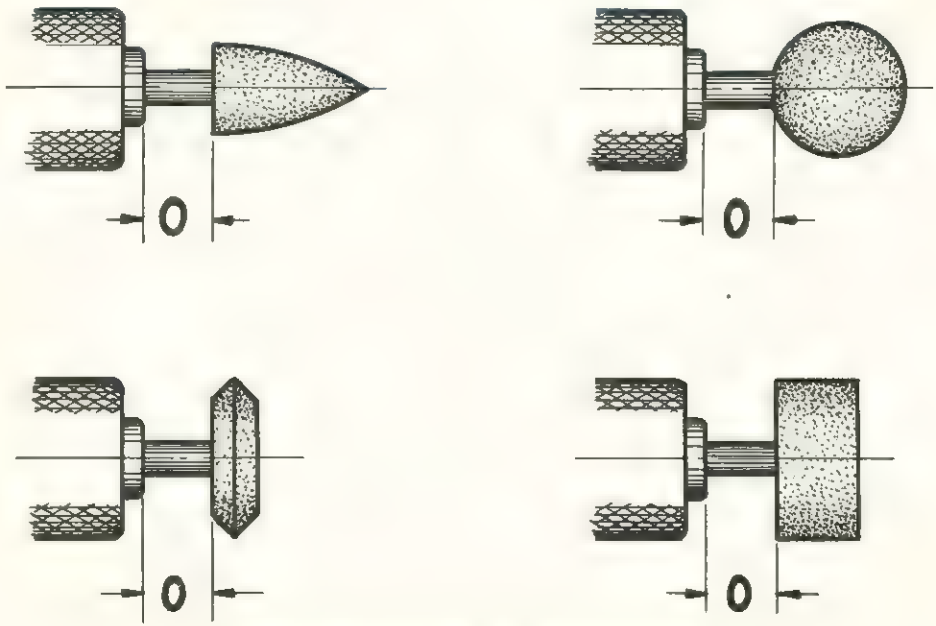
*Indicates sizes most commonly used.

GROUP W—(PLAIN SHAPES)—(Continued)

Shape No.	Size		Shape No.	Size	
	Diam.	Thickness		Diam.	Thickness
W 172	3/8	1/16	W 210	7/8	1/16
W 173	3/8	1/8*	W 211	7/8	1/8*
W 174	3/8	1/4*	W 212	7/8	1/4*
W 175	3/8	3/8*	W 213	7/8	3/8
W 176	3/8	1/2*			
W 177	3/8	3/4*	W 214	15/16	1/4
W 178	3/8	1	W 215	1	1/8*
W 179	3/8	1 1/4*	W 216	1	1/4*
			W 217	1	3/8*
W 180	1/2	1/32	W 218	1	1/2*
W 181	1/2	1/16*	W 219	1	3/4*
W 182	1/2	1/8*	W 220	1	1*
W 183	1/2	1/4*			
W 184	1/2	3/8*	W 221	1	1 1/2
W 185	1/2	1/2*	W 222	1	2
W 186	1/2	3/4*	W 223	1	2 1/2
W 187	1/2	1*	W 224	1	3
W 188	1/2	1 1/2*			
W 189	1/2	2	W 225	1 1/4	1/4*
			W 226	1 1/4	3/8*
W 190	5/8	1/16	W 227	1 1/4	1/2*
W 191	5/8	1/8*	W 228	1 1/4	3/4
W 192	5/8	1/4*	W 229	1 1/4	1
W 193	5/8	3/8*	W 230	1 1/4	1 1/4
W 194	5/8	1/2*	W 231	1 1/4	1 1/2
W 195	5/8	3/4*	W 232	1 1/4	2
W 196	5/8	1	W 233	1 1/4	2 1/2
W 197	5/8	2*	W 234	1 1/4	3
W 198	5/8	2 1/2			
			W 235	1 1/2	1/4
W 199	3/4	1/16*	W 236	1 1/2	1/2
W 200	3/4	1/8*	W 237	1 1/2	1
W 201	3/4	1/4*	W 238	1 1/2	1 1/2
W 202	3/4	3/8*	W 239	1 1/2	2
W 203	3/4	1/2*	W 240	1 1/2	2 1/2
W 204	3/4	3/4*	W 241	1 1/2	3
W 205	3/4	1*			
W 206	3/4	1 1/4	W 242	2	1
W 207	3/4	1 1/2	W 243	2	1 1/2
W 208	3/4	2*	W 244	2	2
W 209	3/4	2 1/2*	W 245	2	2 1/2
			W 246	2	3

*Indicates sizes most commonly used.

TABLES OF
CRITICAL SPEED



Sketches defining dimension "O." See Tables I to VI.

TABLE I

GROUP W—(PLAIN WHEELS)

CRITICAL SPEED (R.P.M.) FOR 1/8" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Wheel Diam.	Wheel Thickness	Overhang—Dimension O (See sketch facing Table I)				
			1/2"	1"	1 1/2"	2"	2 1/2"
W 143	1/8	1/8	140,000	86,000	62,200	43,200	28,500
W 144	1/8	1/4	140,000	86,000	62,200	43,200	28,500
W 145	1/8	3/8	140,000	86,000	62,200	43,200	28,500
W 146	1/8	1/2	140,000	86,000	62,200	43,200	28,500
W 151	3/16	1/8	140,000	86,000	62,200	43,200	28,500
W 152	3/16	1/4	140,000	86,000	62,200	43,200	28,500
W 153	3/16	3/8	107,800	70,000	50,000	35,000	23,500
W 154	3/16	1/2	94,000	60,800	42,000	29,300	20,300
W 157	1/4	1/16	164,000	87,500	63,700	44,200	29,000
W 158	1/4	1/8	140,000	86,000	62,200	43,200	28,500
W 159	1/4	3/16	123,200	76,500	52,500	37,200	25,200
W 160	1/4	1/4	108,500	68,000	45,500	32,000	22,500
W 161	1/4	5/16	103,000	61,300	41,200	30,000	21,500
W 162	1/4	3/8	91,200	56,500	38,500	27,800	20,000
W 163	1/4	1/2	80,000	50,700	35,000	25,000	18,500
W 164	1/4	3/4	61,200	40,000	29,000	21,200	15,800
W 165	5/16	1/16	143,200	83,300	55,000	39,000	27,000
W 166	5/16	1/8	129,300	76,000	47,500	33,500	24,000
W 167	5/16	1/4	100,000	61,000	41,500	30,000	21,000
W 168	5/16	5/16	91,200	55,700	38,200	28,000	20,000
W 169	5/16	3/8	82,200	50,300	36,000	26,500	19,000
W 170	5/16	1/2	70,000	44,000	30,700	22,200	16,800
W 171	5/16	3/4	49,500	34,000	25,000	19,500	14,700
W 172	3/8	1/16	132,500	79,000	54,700	39,000	27,000
W 173	3/8	1/8	116,800	71,000	47,000	33,000	23,000
W 174	3/8	1/4	92,000	55,000	37,000	27,200	20,000
W 175	3/8	3/8	72,000	44,000	32,200	24,000	18,000
W 176	3/8	1/2	60,500	38,000	28,000	21,200	16,200
W 177	3/8	3/4	45,000	31,000	23,500	18,200	13,800
W 178	3/8	1	35,000	25,000	19,000	14,500	11,000

TABLE I—(Continued)

GROUP W—(PLAIN WHEELS)

CRITICAL SPEED (R.P.M.) FOR ⅛" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Wheel Diam.	Wheel Thickness	Overhang—Dimension O (See sketch facing Table I)				
			½"	1"	1½"	2"	2½"
W 181	½	1/16	115,000	74,000	49,000	34,000	23,800
W 182	½	⅛	98,000	58,200	38,800	27,700	20,600
W 183	½	¼	69,000	42,500	30,000	23,000	17,200
W 184	½	⅜	54,700	35,200	26,000	20,000	15,200
W 185	½	½	46,000	30,000	22,500	17,500	13,200
W 186	½	¾	35,000	23,200	17,000	13,000	10,700
W 187	½	1	27,500	18,500	13,500	10,500	8,500
W 190	⅝	1/16	106,000	64,000	42,000	30,200	22,500
W 191	⅝	⅛	78,500	46,000	33,500	25,200	19,000
W 192	⅝	¼	57,500	36,500	26,500	20,300	15,500
W 193	⅝	⅜	47,000	30,700	22,000	16,700	13,000
W 194	⅝	½	39,200	25,500	18,000	14,000	11,000
W 195	⅝	¾	29,500	19,000	13,500	10,200	8,200
W 196	⅝	1	23,500	15,500	10,800	8,200	6,800
W 199	¾	1/16	101,800	59,700	40,000	29,000	21,000
W 200	¾	⅛	73,200	44,700	31,800	23,800	17,800
W 201	¾	¼	51,000	32,500	23,200	17,700	13,300
W 202	¾	⅜	40,800	26,000	18,000	13,500	10,400
W 203	¾	½	34,000	21,200	14,500	11,000	8,800
W 204	¾	¾	25,200	16,000	11,200	8,300	7,000
W 210	⅞	1/16	80,000	47,000	34,300	25,200	19,100
W 211	⅞	⅛	60,800	37,200	27,200	21,100	16,300
W 212	⅞	¼	45,000	27,200	19,200	14,700	12,000
W 213	⅞	⅜	36,000	22,500	15,000	11,000	8,800
W 215	1	⅛	54,800	33,200	24,000	18,500	14,000
W 216	1	¼	40,700	24,800	17,000	12,700	10,000

TABLE II

GROUP W—(PLAIN WHEELS)

CRITICAL SPEED (R.P.M.) FOR $\frac{3}{16}$" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Wheel Diam.	Wheel Thickness	Overhang—Dimension O (See sketch facing Table I)				
			½"	1"	1½"	2"	2½"
W 158	¼	⅛	162,000	89,000	64,000	48,000	35,000
W 159	¼	3/16	150,000	84,000	63,000	46,200	33,500
W 160	¼	¼	138,000	80,000	59,000	44,000	32,000
W 161	¼	5/16	125,000	77,500	57,000	42,500	30,000
W 162	¼	⅜	119,000	75,000	55,000	40,000	29,000
W 163	¼	½	105,000	70,000	52,000	38,500	27,500
W 164	¼	¾	83,000	53,000	40,000	31,000	22,000
W 166	5/16	⅛	158,000	87,000	63,000	47,000	34,000
W 167	5/16	¼	134,000	78,000	58,000	43,500	31,000
W 168	5/16	5/16	124,000	76,000	56,000	41,000	29,500
W 169	5/16	⅜	116,500	73,800	54,500	38,500	28,000
W 170	5/16	½	102,000	63,000	46,000	34,000	25,000
W 171	5/16	¾	76,000	50,000	37,000	29,000	21,000
W 173	⅜	⅛	158,000	87,000	62,000	46,000	33,000
W 174	⅜	¼	131,800	77,000	57,000	43,000	31,000
W 175	⅜	⅜	109,000	67,500	49,000	37,000	27,000
W 176	⅜	½	89,000	57,500	41,800	31,500	23,200
W 177	⅜	¾	72,000	48,000	35,000	27,000	20,000
W 178	⅜	1	56,000	39,000	30,000	23,000	17,200
W 182	½	⅛	123,000	75,000	52,500	39,000	29,000
W 183	½	¼	100,000	63,200	44,500	33,200	25,000
W 184	½	⅜	77,000	53,000	39,000	29,000	21,000
W 185	½	½	66,500	45,000	34,000	26,000	19,500
W 186	½	¾	52,000	37,500	28,500	21,000	16,000
W 187	½	1	43,000	31,000	24,500	18,000	14,000
W 188	½	1½	30,500	23,500	18,500	15,000	.....
W 189	½	2	23,000	18,000	14,000	11,500	.....
W 191	⅝	⅛	111,000	68,500	48,500	36,000	27,000
W 192	⅝	¼	89,000	58,000	41,000	31,200	24,000
W 193	⅝	⅜	70,000	46,500	34,000	25,000	20,000
W 194	⅝	½	59,200	41,500	31,200	24,000	18,000

TABLE II—(Continued)

These are Critical Speeds not Safe Operating Speeds

Shape No.	Wheel Diam.	Wheel Thickness	Overhang—Dimension O (See sketch facing Table I)				
			½"	1"	1½"	2"	2½"
W 195	5/8	3/4	46,000	32,000	24,500	19,000	14,000
W 196	5/8	1	34,500	25,200	20,000	15,500	12,500
W 197	5/8	2	19,700	15,700	11,600	9,700	.....
W 200	3/4	1/8	103,000	65,000	45,000	34,000	26,000
W 201	3/4	1/4	79,000	50,000	37,200	28,500	22,000
W 202	3/4	3/8	61,000	42,000	32,500	24,000	18,500
W 203	3/4	1/2	53,000	36,500	27,500	21,200	16,000
W 204	3/4	3/4	39,000	27,000	20,000	16,000	12,500
W 205	3/4	1	33,000	23,000	17,000	14,000	11,500
W 206	3/4	1 1/4	26,000	19,000	15,000	12,000	9,000
W 207	3/4	1 1/2	22,000	16,500	13,000	10,500	.....
W 208	3/4	2	17,000	12,500	10,000	8,000	.....
W 211	7/8	1/8	97,500	60,000	42,500	32,000	24,500
W 212	7/8	1/4	72,000	46,000	34,500	26,500	19,500
W 213	7/8	3/8	56,500	37,500	28,500	22,000	16,500
W 215	1	1/8	93,000	59,000	41,500	31,500	24,000
W 216	1	1/4	68,000	45,000	33,000	25,500	19,000
W 217	1	3/8	52,500	36,000	26,500	21,000	16,000
W 218	1	1/2	43,700	29,500	22,500	17,200	13,800
W 219	1	3/4	33,500	23,500	17,200	13,200	11,200
W 220	1	1	26,000	19,000	15,000	11,500	9,500
W 221	1	1 1/2	17,500	12,500	9,500	8,000	.....
W 222	1	2	12,000	9,500	7,500	6,500	.....
W 225	1 1/4	1/4	57,400	38,500	28,300	21,700	16,400
W 226	1 1/4	3/8	44,400	29,500	21,800	17,000	13,700
W 227	1 1/4	1/2	37,000	25,500	18,600	14,200	11,600
W 228	1 1/4	3/4	27,500	19,500	14,700	11,700	9,500
W 229	1 1/4	1	22,000	16,000	11,500	9,200	7,700
W 230	1 1/4	1 1/4	17,700	12,200	9,300	7,600	.....
W 231	1 1/4	1 1/2	13,700	9,700	8,000	6,800	.....
W 232	1 1/4	2	10,000	8,000	6,500	6,000	.....
W 235	1 1/2	1/4	51,500	33,200	25,200	20,200	15,700
W 236	1 1/2	1/2	36,300	25,000	18,500	14,000	11,500
W 237	1 1/2	1	21,000	15,000	10,500	8,500	7,500
W 238	1 1/2	1 1/2	13,200	9,300	7,300	6,500	.....

TABLE III
GROUP W—(PLAIN WHEELS)
CRITICAL SPEED (R.P.M.) FOR ¼" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Wheel Diam.	Wheel Thickness	Overhang—Dimension O (See sketch facing Table I)				
			½"	1"	1½"	2"	2½"
W 176	⅜	½	108,000	72,500	56,000	44,000	34,000
W 177	⅜	¾	88,000	62,000	47,000	36,500	28,000
W 178	⅜	1	73,600	54,000	40,000	31,000	23,000
W 179	⅜	1¼	61,000	45,000	34,300	26,300	.....
W 182	½	⅛	145,000	83,200	61,000	47,200	36,700
W 183	½	¼	111,200	73,000	54,000	41,500	32,000
W 184	½	⅜	95,000	63,500	46,700	36,000	27,800
W 185	½	½	82,000	56,000	42,000	32,000	24,500
W 186	½	¾	68,000	48,500	37,000	28,300	21,500
W 187	½	1	54,000	40,000	32,000	25,000	19,000
W 188	½	1½	40,500	32,000	25,200	20,000	.....
W 189	½	2	32,000	25,000	20,000	16,200	.....
W 190	⅝	1/16	161,500	87,500	64,000	50,000	38,700
W 191	⅝	⅛	135,200	80,000	59,000	46,000	36,000
W 192	⅝	¼	108,000	69,000	51,200	39,700	31,000
W 193	⅝	⅜	89,500	60,000	44,500	34,500	26,800
W 194	⅝	½	75,200	53,000	39,200	30,300	23,200
W 195	⅝	¾	62,000	43,200	33,200	26,300	20,500
W 196	⅝	1	47,000	36,000	28,400	22,500	17,500
W 197	⅝	2	28,000	22,000	17,200	14,500	.....
W 198	⅝	2½	22,000	17,200	14,500	.....	.....
W 201	¾	¼	106,000	68,700	50,800	38,700	30,000
W 202	¾	⅜	86,000	58,800	43,200	33,500	25,800
W 203	¾	½	73,800	48,500	37,000	29,000	22,500
W 204	¾	¾	57,000	41,000	31,000	24,000	18,700
W 205	¾	1	46,000	34,500	26,000	20,000	16,000
W 206	¾	1¼	38,300	28,700	22,700	18,000	.....
W 207	¾	1½	32,000	24,700	19,500	16,000	.....
W 208	¾	2	25,000	20,500	16,000	13,200	.....
W 209	¾	2½	20,000	16,200	14,000	.....	.....
W 211	⅞	⅛	130,000	80,000	57,200	44,000	35,000
W 212	⅞	¼	99,000	63,000	46,800	36,800	28,500
W 213	⅞	⅜	81,500	54,500	39,200	31,200	24,500

TABLE III—(Continued)
GROUP W—(PLAIN WHEELS)
CRITICAL SPEED (R.P.M.) FOR ¼" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Wheel Diam.	Wheel Thickness	Overhang—Dimension O (See sketch facing Table I)				
			½"	1"	1½"	2"	2½"
W 215	1	⅛	126,000	78,500	58,000	45,000	34,000
W 216	1	¼	95,200	61,000	45,000	35,000	27,000
W 217	1	⅜	76,000	51,000	38,000	30,000	23,200
W 218	1	½	64,000	43,700	33,200	26,000	19,800
W 219	1	¾	46,800	32,700	25,000	20,000	16,000
W 220	1	1	34,000	25,500	21,000	16,500	14,000
W 221	1	1½	25,500	19,500	16,000	14,000	.....
W 222	1	2	21,200	16,500	13,000	11,500	.....
W 223	1	2½	16,500	13,200	11,500	.....	.....
W 225	1¼	¼	86,000	57,200	42,200	32,000	25,000
W 226	1¼	⅜	68,200	47,000	35,000	26,800	21,000
W 227	1¼	½	54,700	39,500	30,200	24,000	18,800
W 228	1¼	¾	40,700	30,000	23,800	19,000	15,200
W 229	1¼	1	32,000	25,000	20,500	16,000	13,200
W 230	1¼	1¼	27,200	21,200	17,000	14,000	.....
W 231	1¼	1½	23,500	18,000	14,200	12,000	.....
W 232	1¼	2	19,000	14,200	12,000	10,000	.....
W 235	1½	¼	67,000	48,500	38,300	30,300	23,500
W 236	1½	½	48,200	36,200	29,000	23,000	18,200
W 237	1½	1	30,000	23,500	17,700	14,500	12,700
W 238	1½	1½	20,800	16,000	13,000	11,000	.....

TABLE IV

GROUP B—(SHAPED WHEELS)

CRITICAL SPEEDS (R.P.M.) FOR ⅛" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Max. Diam.	Max. Thickness	Overhang—Dimension O (See sketch facing Table I)				
			½"	1"	1½"	2"	2½"
B 41	5/8	5/8	45,000	31,000	23,500	18,200	13,800
B 42	½	¾	45,000	31,000	23,500	18,200	13,800
B 43	¼	1/16	108,500	68,000	45,500	32,000	22,500
B 44	7/32	5/8	91,200	56,500	38,500	27,800	20,000
B 45	3/16	5/16	139,000	82,500	59,500	41,200	27,000
B 46	⅛	5/16	140,000	86,000	62,200	43,200	28,500
B 47	⅛	5/32	140,000	86,000	62,200	43,200	28,500
B 51	7/16	¾	60,500	38,000	28,000	21,200	16,200
B 52	3/8	¾	60,500	38,000	28,000	21,200	16,200
B 53	¼	5/8	80,000	50,700	35,000	25,000	18,500
B 54	¼	½	80,000	50,700	35,000	25,000	18,500
B 55	⅛	¼	140,000	86,000	62,200	43,200	28,500
B 61	¾	5/16	51,000	32,500	23,200	17,700	13,300
B 62	½	3/8	54,700	35,200	26,000	20,000	15,200
B 63	¼	1/16	123,200	76,500	52,500	37,200	25,200
B 64	¼	1/16	140,000	86,000	62,200	43,200	28,500
B 65	⅛	⅛	140,000	86,000	62,200	43,200	28,500
B 71	5/8	3/32	106,000	64,000	42,000	30,200	22,500
B 72	½	⅛	98,000	58,200	38,800	27,700	20,600
B 73	½	⅛	98,000	58,200	38,800	27,700	20,600
B 74	7/32	3/32	140,000	86,000	62,200	43,200	28,500
B 81	¾	3/16	92,000	55,000	37,000	27,200	20,000
B 82	½	¼	108,500	68,000	45,500	32,000	22,500
B 83	3/8	⅛	116,800	71,000	47,000	33,000	23,000
B 84	5/16	3/16	140,000	86,000	62,200	43,200	28,500
B 91	½	5/8	46,000	30,000	22,500	17,500	13,200
B 92	¼	¼	108,500	68,000	45,500	32,000	22,500
B 93	3/16	3/16	140,000	86,000	62,200	43,200	28,500
B 94	11/64	3/32	140,000	86,000	62,200	43,200	28,500
B 95	⅛	1/16	140,000	86,000	62,200	43,200	28,500
B 96	⅛	¼	140,000	86,000	62,200	43,200	28,500
B 97	3/32	3/8	140,000	86,000	62,200	43,200	28,500

TABLE IV (Continued)

GROUP B—(SHAPED WHEELS)

CRITICAL SPEEDS (R.P.M.) FOR ⅛" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Max. Diam.	Max. Thickness	Overhang—Dimension O (See sketch facing Table I)				
			½"	1"	1½"	2"	2½"
B 98	3/32	¼	140,000	86,000	62,200	43,200	28,500
B 101	⅝	11/16	45,000	31,000	23,500	18,200	13,800
B 102	⅝	½	60,500	38,000	28,000	21,200	16,200
B 103	⅝	3/16	92,000	55,000	37,000	27,200	20,000
B 104	5/16	⅜	91,200	56,500	38,500	27,800	20,000
B 105	¼	¼	139,000	82,500	59,500	41,200	27,000
B 106	⅛	7/64	140,000	86,000	62,200	43,200	28,500
B 111	7/16	11/16	45,000	31,000	23,500	18,200	13,800
B 112	⅜	½	60,500	38,000	28,000	21,200	16,200
B 113	¼	¼	108,500	68,000	45,500	32,000	22,500
B 114	7/32	⅜	91,200	56,500	38,500	27,800	20,000
B 115	3/32	⅛	140,000	86,000	62,200	43,200	28,500
B 121	½	½	60,500	38,000	28,000	21,200	16,200
B 122	⅜	⅜	82,200	50,300	36,000	26,500	19,000
B 123	5/16	5/16	139,000	82,500	59,500	41,200	27,000
B 124	⅛	⅛	140,000	86,000	62,200	43,200	28,500
B 131	½	½	46,000	30,000	22,500	17,500	13,200
B 132	⅜	½	60,500	38,000	28,000	21,200	16,200
B 133	⅜	⅜	72,000	44,000	32,200	24,000	18,000
B 134	5/16	⅜	82,200	50,300	36,000	26,500	19,000
B 135	¼	½	80,000	50,700	35,000	25,000	18,500
B 136	¼	5/16	103,000	61,300	41,200	30,000	21,500

TABLE V

GROUP B—(SHAPED WHEELS)

CRITICAL SPEEDS (R.P.M.) FOR ¼" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Max. Diam.	Max. Thickness	Overhang—Dimension O (See sketch facing Table I)				
			½"	1"	1½"	2"	2½"
B 41	5/8	5/8	88,000	62,000	47,000	36,500	28,000
B 42	1/2	3/4	88,000	62,000	47,000	36,500	28,000
B 51	7/16	3/4	108,000	72,500	56,000	44,000	34,000
B 52	3/8	3/4	108,000	72,500	56,000	44,000	34,000
B 61	3/4	5/16	106,000	68,700	50,800	38,700	30,000
B 62	1/2	3/8	95,000	63,500	46,700	36,000	27,800
B 71	5/8	3/32	161,500	87,500	64,000	50,000	38,700
B 72	1/2	1/8	145,000	83,200	61,000	47,200	36,700
B 73	1/2	1/8	145,000	83,200	61,000	47,200	36,700
B 74	7/32	3/32	.....	.....	.....	.....	.....
B 91	1/2	5/8	82,000	56,000	42,000	32,000	24,500
B 101	5/8	11/16	88,000	62,000	47,000	36,500	28,000
B 102	5/8	1/2	108,000	72,500	56,000	44,000	34,000
B 111	7/16	11/16	88,000	62,000	47,000	36,500	28,000
B 112	3/8	1/2	108,000	72,500	56,000	44,000	34,000
B 121	1/2	1/2	108,000	72,500	56,000	44,000	34,000
B 131	1/2	1/2	82,000	56,000	42,000	32,000	24,500
B 132	3/8	1/2	108,000	72,500	56,000	44,000	34,000

TABLE VI

GROUP A—(SHAPED WHEELS)

CRITICAL SPEED (R.P.M.) FOR ¼" SPINDLES

These are Critical Speeds not Safe Operating Speeds

Shape No.	Wheel Diam.	Thickness of Length	Overhang—Dimension O (See sketch facing Table I)					
			½"	1"	1½"	2"	2½"	3"
A 1	¾	2½	26,400	22,000	17,500	14,200	12,000	9,000
A 2	1	1¼	59,000	43,500	34,000	27,500	22,500	18,000
A 3	⅞	2¾	24,000	19,500	16,000	13,000	10,000	7,000
A 4	1¼	1¼	43,000	33,000	27,000	21,500	17,500	14,000
A 5	¾	1⅛	60,000	45,000	36,000	28,000	22,000	18,000
A 6	¾	1⅛	52,000	39,600	32,000	25,300	20,000	16,000
A 11	1⅛	1¾	36,700	29,200	24,000	19,500	16,000	12,500
A 12	1⅛	1¼	64,000	47,000	36,500	29,000	23,000	18,000
A 13	1⅛	1⅛	57,000	43,000	34,000	27,500	22,000	17,000
A 14	1⅛	⅞	76,000	54,000	41,000	32,500	26,000	20,000
A 15	¼	1 1/16	97,000	63,500	46,000	35,000	26,500	18,500
A 21	1	1	46,000	35,000	28,000	23,000	18,500	14,500
A 22	¾	⅝	76,000	54,000	41,000	32,500	26,000	20,000
A 23	¾	1	52,500	40,500	32,500	26,000	20,000	16,000
A 24	¼	¾	102,000	66,000	48,500	36,000	27,000	20,500
A 25	1	1	47,500	36,500	29,500	24,000	19,000	15,000
A 26	⅝	⅝	92,000	62,000	47,000	37,000	28,500	21,000
A 31	1⅜	1	45,000	35,000	28,000	23,000	18,000	14,500
A 32	1	⅝	72,000	52,000	40,000	32,000	25,200	20,000
A 33	1	½	72,000	52,000	40,000	32,000	25,200	20,000
A 34	1½	⅜	64,000	46,000	36,000	29,300	24,000	18,500
A 35	1	⅜	79,000	56,000	42,000	34,000	27,000	21,200
A 36	1⅝	⅜	64,000	45,000	35,500	29,000	23,500	18,500
A 37	1¼	¼	88,000	62,000	47,000	37,500	30,000	24,000
A 38	1	1	46,000	35,000	28,000	22,700	18,000	14,200
A 39	¾	¾	63,000	47,000	37,000	29,500	23,000	17,500

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